ELSEVIER

Available online at www.sciencedirect.com
ScienceDirect

Procedia Earth and Planetary Science 1 (2009) 1744–1750

Procedia Earth and Planetary Science

www.elsevier.com/locate/procedia

The 6th International Conference on Mining Science & Technology

Differences in coal consumption patterns and economic growth between developed and developing countries

Li Jin-ke[a,b,]*, Wang Feng-hua[b], Song Hua-ling[b]

[a]*Civil and Environmental Engineering School, University of Science and Technology Beijing, Beijing 100083, China*
[b]*School of Management Science and Engineering, Shandong Institute of Business and Technology, Yantai 264005, China*

Abstract

There exist different energy mixes, different fuel use patterns, and different consumption trends between developed and developing countries. Will causal relationship between coal consumption and economic growth different? This paper uses the granger causality test procedure to examine the differences of causal relationships between coal consumption and GDP in major developed and developing countries based on data during the period from 1980 to 2005. Although no similar causal relationship between coal consumption and GDP in major developed and developing countries has been discovered, they all should examine how coal use is linked with economic development and make a scientific policy for coal energy to cut carbon dioxide (CO_2) emissions to meet the standards stipulated in the Kyoto Protocol.

Keywords: causality relationship; coal consumption; developed countries; developing countries

1. Introduction

Diverse, secure, affordable, and environmentally acceptable supplies of energy are essential to sustainable development of world societies [1]. Long term global economic growth cannot be achieved without adequate and affordable energy supplies, which will require continuing significant contributions from fossil fuels, including coal.

Coal, which has the greatest importance among the energy sources, is the primary factor for the industrial revolution in the world. Countries that found their coal reserves and used them in the 19th century are now developed countries of the world. Coal keeps its favor even today and higher prices for oil and natural gas making coal more competitive. So coal has again becomes the world's fastest growing fuel in 2005, with global consumption rising by 5% or twice the 10-year average. In the IEO2007 reference case, world coal consumption increases by 74 % over the projection period, from 114.4 quadrillion Btu in 2004 to 199.0 quadrillion Btu in 2030 [1]. High oil and gas prices are driving demand for coal; however economic growth is among the most important factors to be considered in projecting changes in the world's energy consumption, thus it is important to analyze the relationship between coal consumption and economic growth.

* Corresponding author. Tel.: +86-535-6903575; fax: +86-535-6905953.
E-mail address: jinkeli@yahoo.com.cn.

doi:10.1016/j.proeps.2009.09.267

Although coal has played a decisive role in maintaining and promoting the steady growth of the world economy, coal consumption pattern and trend in developed countries are much different from developing countries. There are wide differences in average indicators of coal use between developing and industrial countries.

With the Kyoto Protocol which requires participating countries to reduce their carbon dioxide emissions collectively to an annual average of about 5 percent below their 1990 level over the 2008-2012 period, becoming a legally binding treaty on February 16, 2006, both the developed and developing world need to take appropriate actions. Coal consumption patterns in participating countries will inevitably effected. Both the developed and developing world have increasingly realized the importance of reducing global greenhouse emissions. Consequently, is it necessary to abandon the burning of coal to protect the earth from unprecedented climate change? Will coal consumption reduction cause economic shocks? Is there a “causal” relationship between coal consumption and economic growth, are the “causal” in developed the same as and developing countries then to adopt alike policies?

2. Review of the literatures

Since the pioneering study of Kraft, J., Kraft, A. found that there was a unidirectional causality running from energy consumption to GNP for the United States during the period of 1947-1974, more literatures are focused on causality relationship and long run cointegration relationship between energy consumption and GDP [2]. Soytas and Sari carefully studied the causality relationship in G-7 countries and emerging markets [3]; Chien-Chiang Lee analyzed the cases of 11 major industrialized countries [4]. In recent years the causality relationship analysis was also applied in developing Asia and other countries; Oh and Lee had analyzed the case of Korea 1970-1999 [5]; Lee, C.C presented the examples in 18 developing countries except China [6]. Al-Iriani made an example in GCC countries using panel causality. Besides, the coverage was also extended to electricity [7]. Yoo studied the causality relationship between electricity consumption and economic growth in the ASEAN countries [8]; Ferguson et al. had studied the matter in over 100 countries, and found that as a whole there was a strong correlation between electricity consumption and economic growth [9]. Alice Shiu and Sajal Ghosh gave the examples of electricity consumption and economic growth in China and India respectively [10-11]; Narayan provided Electricity consumption and real GDP causality for 30 OECD countries [12]. In recent years the researchers had begun to analyze the causality relationship between coal consumption and economic growth. Yang found causality relationship from economic growth to coal consumption in Taiwan [13]; Yoo’s study showed that there existed bi-directional causality relationship between coal consumption and economic growth in South Korea [14]. However there have been few studies specifically addressing coal consumption with economic growth.

3. Coal consumption in developed and developing countries

3.1. Different energy mixes

Not only do developed and developing countries show wide disparities in energy consumption per capita, but they also exhibit different trends in the composition of energy types consumed as well (shown in Fig. 1).

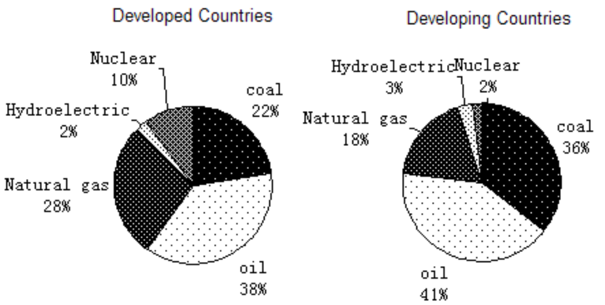

Fig. 1. Energy mixes in developed and developing countries 2003

With all developed countries, petroleum is consumed the most, but the next most consumed energy source in the developing world is coal, while it is natural gas for the high-income countries. Among the developing countries, hydropower is the next most consumed energy source after natural gas, while the developed countries consume more nuclear energy than hydropower. Coal, in contrast, stands out as an affordable resource that is relatively straightforward to convert to electrical power. It is also abundant and reliable and will inevitably form a significant part of the future energy mix in many developing countries.

3.2. Different fuel-use patterns

Fuel-use patterns in the developing countries were generally more carbon-intensive than in the developed countries over the past two decades. Carbon dioxide emissions grew fastest in the developing world in the 1980s and 1990s, see Fig. 2. Most of the growth in worldwide energy consumption and carbon dioxide emissions over the past two decades took place in large, developing countries such as China, India, and South Korea.

The relationship between economic development and energy use varies significantly across country groups. In the developed countries, real gross domestic product (GDP) grew faster than energy use between 1980 and 2001, indicating the developed economies' increasing reliance upon comparatively non-energy-intensive sectors. In the majority of developing countries outside developing Asia, development and energy use remain closely correlated. Will causal relationship between coal consumption and economic growth different?

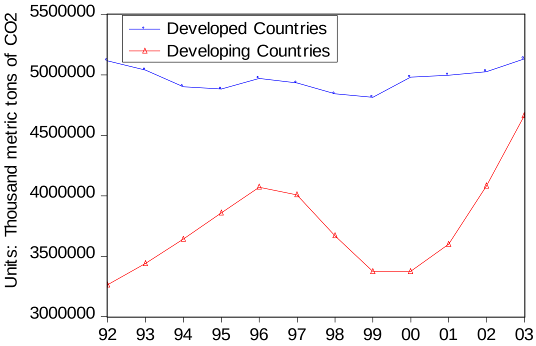

Fig. 2. CO_2 emissions from solid fuels in developed countries and developing countries

4. Methodology and results

Although competitive cost coal resources are relatively abundant worldwide, most world consumption of coal is accounted for by just five countries-China, the United States, India, Japan, Russia and South Africa. Therefore, the paper takes the major developed-United States (USA), Japan (JP) and developing countries-PR of China (CN), India (IN) and South Africa (SA) as example, to study the causal relationships between coal consumption and economy.

The data used in this study consist of annual time series of real GDP are obtained from International Monetary Fund [15]. Real GDP is expressed in billions of national currency units; the base year is country specific. Coal consumption is from BP [1], the unit is expressed in Million tones oil equivalent. The testing process is completed with EViews5.1; the empirical period depends on the availability of data, where the time period used is 1980-2005 with all variables measured in natural logarithms.

On the methodological front, standard tests based on Granger [16] and Stern [17] causality techniques have been widely used. The test is quite simple and straightforward. A time series (LnG) is said to Granger-cause another time series (LnC) if the prediction error of current LNC declines by using past values of LNG in addition to past values of LNC. In order to conduct the Granger-causality test, a series of variables is required to be stationary. It has been shown that using non-stationary data in causality tests can yield spurious causality results. Therefore, following Engle and Granger, the author first tests the unit roots of LNG and LnC to confirm the stationarity of each variable.

4.1. Unit root test

In order to examine the stationarity of each variable, we employ the Augmented Dickey Fuller (ADF) test to examine the possibility of a unit root among these variables, and the results of the unit root test are presented in Table1. Akaike's Information Criterion (AIC) is adopted in order to select the optimal number of lag length.

As shown in Table 1, The results of the ADF unit root tests for levels and first differences show that in all countries, LnC and LnG appear to be I (1) variables except for LnG of USA. The ADF test indicates that the series of all the variables are non stationary at 5% level of significance except for LnG of USA, thus any causal inferences from the two series in levels are invalid. However, non stationary can be rejected for first-differences of these series at 5% level of significance, except for LnG of Japan at 10% level of significance.

Table 1. Results of unit root tests

Countries	Variable	LnG			LnC		
		(C, T, K)	*ADF*	Critical values	(C, T)	*ADF*	Critical values
Developed countries							
US							
	Level	(C, T, 5)	-4.2001	-3.6584	(C, T, 0)	-2.0919	-3.6032
	1st difference				(C, 0, 0)	-5.1417	-2.9919
JP							
	Level	(C, T, 1)	-1.4552	-3.6122	(C, T, 2)	-0.4378	-3.6220
	1st difference	(C, T, 1)	-3.2497	-3.2486*	(C, T, 1)	-6.6079	-3.6220
Developing countries							
CN							
	Level	(C, T, 3)	-3.0850	-3.6328	(C, T, 1)	-3.2199	-3.6122
	1st difference	(C,0, 3)	-3.5492	-3.0124	(C, 0, 4)	-3.4891	-3.0206
IN							
	Level	(C, T, 1)	-3.4205	-3.6122	(C, T, 0)	-1.3554	-3.6032
	1st difference	(C, 0, 2)	-4.3718	-3.0049	(C,0, 0)	-5.3645	-3.6122
ZA							
	Level	(C, T, 1)	-1.0002	-3.6122	(C, T, 1)	-3.2918	-3.6122
	1st difference	(C, T, 1)	-4.0421	-3.6220	(C, T, 0)	-4.2998	-3.6122

Note: in (C, T, K) C, T K means constant, trend and lag length in unit root test, respectively if the value is zero it means that there does not exist constant or trend or the lag length is zero; default critical value is significant at 5% significance level; *indicates significance at 10% level. LnG denotes natural logarithms of GDP; Ln denotes natural logarithms of coal consumption.

Thus Granger-causality models are estimated with first-differenced data, while cointegration test cannot be done for USA as LnG and LnC of USA are not integrated of the same order.

4.2. Cointegration tests

According to Engle and Granger [16], if two time serials are both non stationary, while the linear combination of two time serials would be stationary, thus, the two time serials are cointegrated. Tests of cointegration include the simple two-step test by Engle and Granger [16] (EG) and Johansen's vector auto regression (VAR). As two time serials of LnG and LnC tested for cointegration, two-step test EG is used in this paper.

First, Estimate cointegration equation is of the following form:

$$LnG_t = \alpha + \beta LnC_t + \varepsilon_t$$

To obtain $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\varepsilon} = LnG_t - \hat{\alpha} - \hat{\beta} LnC_t$

Second, if *ADF* test indicates $\hat{\varepsilon} \sim I\ (0)$, thus ε_t is stationary, LnG and LnC are cointegrated.

Having OLS estimated the above model of coal consumption and GDP series, ADF test for ε_t is conducted. Table 2 indicates that test results on the levels of GDP and coal consumption at the corresponding significance level.

The results strongly support the conclusion that a long run relationship of between the variables does exist for Japan, China, India and South Africa.

Table 2. Results of unit root tests for $\hat{\varepsilon}$

$\hat{\varepsilon}$	JP	CN	IN	ZA

(C, T, K)	(0, 0, 3)	(0, 0, 1)	(0, 0, 5)	(C, T, 0)
ADF	-2.5921	-2.7676	-2.4592	-3.4849
Critical values	-1.9572	-2. 6649**	-1.9591	-3.2381*

Note: Default critical value is significant at 5% significance level; ** and * indicate significance at the 10% and 1% significance level, respectively.

4.3. Granger causality tests

Cointegration implies the existence of granger causality, however, it does not point out the direction of the causality relationship. Therefore, the vector error correction (VER) model is employed to detect the direction of the causality. Engle and Granger (1987) argued that if there is cointegration between the series, then the vector error-correction model can be written as:

$$\Delta LnG_t = \lambda_1 + \sum_{i=1}^{k} \alpha_{1i} \Delta LnG_{t-i} + \sum_{i=1}^{k} \beta_{1i} \Delta LnC_{t-i} + \gamma_1 ecm_{1t-1} + \varepsilon_{1t}$$

$$\Delta LnC_t = \alpha_{20} + \sum_{j=1}^{m} \alpha_{2j} \Delta LnC_{t-j} + \sum_{j=1}^{m} \beta_{2j} LnG_{t-j} + \gamma_2 ecm_{2t-1} + \varepsilon_{2t}$$

where Δ is the difference operator, k; m the numbers of lags; $\beta_{,s}$ are parameters to be estimated; ecm represents the error terms derived from the long run co-integration relationship; $LnG_t = \alpha + \beta LnC_t + \varepsilon_t$, and $\varepsilon_{,s}$ the serially uncorrelated error terms.

In each equation, the change in the dependent variable is caused not only by their lags, but also by the previous period's disequilibrium in level. The results of the Granger causality tests of the model are reported in Table 3. The table also reports the tests used to choose the lag lengths.

The results presented in Table 3 provide convincing evidence of a unidirectional causality running from LnG to LnC for Japan and China at the 5% level of significance. However, no evidence is found on the causality relationship between coal consumption and GDP for India and South Africa at the same significance levels.

Table 3. Results of causality tests based on ECM

	Null hypotheses	p-values	Lags	Direction of causality
		Developed countries		
JP	*LnC≠ LnG*	0.1700	3	$LnC \neq> LnG$
	LnG≠ >LnC	0.0360		$LnG \Rightarrow LnC$
		Developin g countries		
CN	$LnC \neq> LnG$	0.8813	2	$LnC \neq> LnG$
	$LnG \neq> LnC$	0.0488		$LnG \Rightarrow LnC$
IN	$LnC \neq> LnG$	0.8646	2	$LnC \neq> LnG$
	$LnG \neq> LnC$	0.7262		$LnG \neq> LnC$
ZA	$LnC \neq> LnG$	0.5593	2	$LnC \neq> LnG$
	$LnG \neq> LnC$	0.2589		$LnG \neq> LnC$

Notes: the lag lengths are chosen by using AIC criterion; the statistics are p-values calculated under the null hypothesis of no causation. $\neq>$ denotes statistical insignificance and, hence fails to reject the null hypothesis of non-causality. $\Rightarrow$ denotes the rejection of the null hypothesis of non-causality.

5. Conclusion and policy implications

With the United Nations' framework convention on climate change's Kyoto Protocol coming into force, not only developed countries but also developing countries are expected to cut their greenhouse gas emissions, especially carbon dioxide (CO_2) emissions to meet the standards stipulated in the Kyoto Protocol. For developing countries, the coal consumption ratio is high in the energy consumption structure; these countries strongly feel that economic development must be considered in first priority in energy strategy, would the cut of coal consumption to reduce

CO_2 emissions lead to a reduction in GDP? As the coal consumption trend and energy structure of developed countries and developing countries are different, will the effects be different?

This paper provides the answer to this question and discusses possible policy implications. The main conclusion that emerges from the exercise is that the causal relationship between coal consumption and GDP is not uniform across developed countries but also developing countries.

First, the results indicate that unidirectional causality running from GDP to coal consumption exists in Japan and China. This means that continuous economic growth simultaneously generates a continuous rise in coal consumption. In this case, coal consumption is fundamentally driven by GDP; taking measures to conserve coal may be feasible without compromising economic growth. Beyond this, it is implied that a strategy for sustainable development with a lower level of CO_2 emissions may, indeed, be appropriate in these three countries.

Second, the results do not identify any causality relationship between coal consumption and GDP in the India and South Africa. This implies that decoupling the limitations on CO_2 emissions from economic growth can be achieved. That is, sustainable development strategies with lower levels of CO_2 emissions from coal combustion may be reached. Simply India and South Africa may take greater responsibility to reduce their CO_2 emissions because such a reduction in coal consumption would not significantly affect economic growth.

Finally, the observed cross-country diversity in the causal pattern is not altogether unexpected. Energy consumption structures and economic policies, which are known to differ across countries, make it natural to expect a certain degree of cross-country variability in the causality between coal consumption and economic growth. The reason may lies in that each country has different economic development and coal consumption patterns; further research may be needed to address this issue, such as this analysis should be readily extended to other multivariate systems, where coal consumption and GDP are exposed to be determined by other economic factors such as price, employment, exports, etc. Meanwhile as to other developed countries and developing countries, the granger causality test has not been conducted.

Acknowledgements

Financial support for this work, provided by the National Natural Science Foundation of China (70771060), is gratefully acknowledged.

References

[1] BP. The BP Statistical Review of World Energy 2007. Http: // www.bp.com /statistical review, 2007. International Energy Agency, Coal Information (2005 Edition).

[2] J. Kraft and A. Kraft, On the relationship between energy and GNP. Journal of Energy Development. 3 (1978) 401-403.

[3] U. Soytas and R. Sari, Energy consumption and GDP: causality relationship in G-7 countries and emerging markets. Energy Economics. 25 (2003) 33-37.

[4] S.T. Chen and H.I. Kuo, The relationship between GDP and electricity consumption in 10 Asian countries. Energy Policy. 35 (2007) 2611-2621.

[5] W. Oh and K. Lee, Causal relationship between energy consumption and GDP revisited: the case of Korea 1970-1999. Energy Economics. 26 (2004) 51-59.

[6] C.C. Lee, Energy consumption and economic growth in Asian economies: A more comprehensive analysis using panel data. Resource and Energy Economics. 30 (2008) 50-65.

[7] M.A. Al-Iriani, Energy-GDP relationship revisited: An example from GCC countries using panel causality. Energy Policy. 34 (2006) 3342-3350.

[8] S. Yoo, The causal relationship between electricity consumption and economic growth in the ASEAN countries. Energy Policy. 34 (2006) 3573-3582.

[9] R. Ferguson, W. Wilkinson and R. Hill, Electricity use and economic development. Energy Policy. 28 (2000) 923-934.

[10] A. Shiu and P.L. Lam, Electricity consumption and economic growth in China. Energy Policy. 32 (2004) 47-54.

[11] S. Ghosh, Electricity consumption and economic growth in India. Energy Policy. 30 (2002) 125-129.

[12] P. K. Narayan and A. Prasad, Electricity consumption-real GDP causality nexus: Evidence from a bootstrapped causality test for 30

OECD countries. Energy Policy In Press, Corrected Proof.

[13] H.Y. Yang, Coal Consumption and Economic Growth in Taiwan. Energy Sources. 22 (2000) 109-115.

[14] S. Yoo, Causal relationship between coal consumption and economic growth in Korea. Applied Energy. 83 (2006) 1181-1189.

[15] International Monetary Fund (IMF). World Economic Outlook (WEO) Database October 2007 Edition. http://www.imf.org/external/pubs/ft/weo/2007/02/weodata/index.aspx.

[16] R. Engle and C. Granger, Cointegration and error correction: representation, estimation, and testing. In Econometrica. 55 (1987) 257-276.

[17] D.I. Stern, Multivariate cointegration analysis of the role of energy in the US macroeconomy. Energy Economics. 22 (2000) 267-283.